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Introduction

There are three major institutions that publish *worldwide* population projections: the United Nations Population Division, the US Bureau of the Census and the International Institute for Applied Systems Analysis (IIASA). In the following analyses we will only use the *most recent* edition of the UN Population Assessments and Projections which was completed in November 1996. So far, these UN projections have not been officially published - but we had access to an internal data compendium ("Annex I and II") that will be included in the official publication. The final report of the 1996 UN population projections will be published in early 1997.

We have, of course, also considered using the projections from the IIASA population program (Lutz, 1996) or that of the US Bureau of the Census (1996a). However, the IIASA population scenarios are only available for 13 very large world *regions* which are ecologically much too diverse for studying linkages between population and land or water resources. The projections of the US Bureau of the Census, on the other hand, are available for specific countries, but cover only the period from 1996 to 2020. This time-frame might be adequate from a methodological point of view, but is rather short for investigating resource constraints. The projections also do not include any indication about the range of uncertainty - such as a lower and higher variant or a probability range. Only the UN Population Assessments and Projections are available for all *countries* worldwide, include a higher and lower variant, and provide data series ranging from 1950 to 2050 which are long enough for bio-physical research. Moreover, only the UN population projections, which are now published every second year, have a history of more than four decades which makes it possible to assess their predictive accuracy. The World Bank, which formerly published its own projections (Vu, 1985) has canceled this activity and uses the UN data.

1. Major Demographic Trends

1.1 World population will grow *significantly* - in spite of falling fertility.

There is one most striking paradox in global population trends: on one hand we have a rapid *decline* of fertility for more than two decades in many developing countries - not to speak about the already extremely low fertility in most highly developed nations; on the other hand we recently had the *largest annual increase of world population in history*. Between 1990 and 1995 *each year* some 85 million people were added to the world population. Why is this the case and what are recent estimates of fertility and population growth?

According to the most recent UN assessment fertility - measured as a global *average* - began to decline in the mid-1970s. The world population, however will almost certainly continue to grow for several decades to come (see Figure 1). According to the UN medium variant projection we will most likely have a global population of about 9.4 billion by 2050. This is somewhat lower than the Population Division's previous estimate of 9.8 billion in the 1994 edition of the World Population Estimates.

Even if one assumes *extremely* rapid worldwide fertility decline to an *average* of 1.5 children per woman - which most demographers would consider highly unlikely - we would see a further increase of the world population up to about 7.6 billion people by 2050 (see UN low fertility variant). However, it is not impossible that the global population might increase to more than 11 billion by 2050. Please note that this "high" UN variant still assumes a worldwide fertility *decline* from currently 2.9 to about 2.6 children per woman (see Figure 1 and Table 1).

1.2 The current *annual* population increase of 80 million will probably remain constant until 2015.

Currently world population is growing by about 80 million people per year (see Figure 2). This is a little less than in the early 1990s when the growth was more than 85 million per year. According to the most recent UN medium variant projection this will not change much during the next decades. Only after 2015 will we observe a gradual decline. By 2050 - according to the UN medium variant - this annual *increase* of the world population will be down to "only" some 50 million. Thus, by the middle of the next century, world population growth (in absolute numbers) will have declined to the level of the early 1950s. However, this is only possible, if fertility - *worldwide* - falls to the so-called "reproductive level" of 2.1 children per woman by 2050. For countries like India, Pakistan or Nigeria that is a long way to go.

It cannot be excluded that some populous countries will not reach this low fertility level by 2050. If - on *average* - worldwide fertility would decline to only 2.6 children per woman, world population growth would further *increase*. Between 2020 and 2050 we would have a global *annual* population increase of about 100 million (see high variant UN projection in Figure 2).

In the near future the current world population increase could only decline, if average fertility - worldwide - would fall to 1.6 (!) children per woman. There are not many demographers who would consider this level of fertility very likely. But only with such an extreme drop in fertility could we observe a shrinking of the world population after 2040 - assuming that there will be no disaster with a massive increase of mortality.

1.3 Between now and 2050 world population growth will be generated *exclusively* in developing Countries.

Between now and the year 2050 world population will most likely increase by some 3.2 billion people - almost *all* of them will be contributed by the developing countries (see Table 2). In fact, the population of the developed nations as a group will most likely decline by almost 59 million people between 2025 and the year 2050. Comparing the centennial growth of developed and developing countries reveals a dramatic divergence: The developed countries as a group will have increased their population by less than 350 million between 1950 and 2050. The developing countries, on the other hand, will have added almost 6.5 *billion* people - thus almost quintupling their 1950 population.

This modern "population explosion" in the Third World - of course - is *not* comparable with anything we have experienced in the demographic transition of Europe during the 18^{th} and 19^{th} century. It is a historically *unique* phenomenon. Both the absolute numbers of population increase and the growth rates are without historical precedence. No country in Europe has experienced annual population growth rates of more than 0.5 to 1 percent during its "high growth" period.

1.4 World population increase is concentrated in Asia.

From the almost 3.7 billion people that will be added to the world population between now and 2050, Asia will contribute 2 billion (see Table 2). This enormous population increase of 2000 million people is due to the already massive size of the population. Most of this growth will happen in the next three decades. Between 1995 and 2025 Asia's population will grow by 1.35 billion - between 2025 and 2050 the increase will be only 658 million (see Table 2).

During the next three decades Africa will contribute another 734 million to the world population - some 15 million *more* than its current total population. Despite a projected increase in mortality due to AIDS we will not observe a significant slow down of population growth in Africa - not to speak about a decline. Fertility is still so high in Sub-Saharan Africa that it easily can offset the effect of rising (infant and adult) mortality. Latin America and the Caribbean, on the other hand, will have only a moderate population increase of some 213 million between 1995 and 2025. This is due to both the smaller initial size of the population and the significant decline of fertility. Europe's population will almost certainly decline. The UN medium variant projection assumes a shrinking by as much as 27 million during the next three decades.

1.5 By far the highest population growth rates can be found in Africa.

While Asia will contribute the largest number of people to modern world population growth, Africa will set the record in growth *rates*. In Table 2 we have calculated *annual* grow rates for various periods and all major regions of the world (we have used true *exponential* growth rates, so that periods of various length can be compared).

Between now and the year 2025 Africa's population is projected to have a exponential annual growth rate of 0.44%, Latin America and the Caribbean will grow by 0.23%, Asia by 0.21%, and Northern America by 0.14%. Europe's population, most likely, will decline by 0.02%.

Please note that these projected growth rates for the next 30 years are actually lower than the historical growth rates during the past 45 years. Between 1950 and 1995 Africa had a exponential annual growth rate of 0.49, Latin America and the Caribbean had 0.44, Asia 0.38 and Northern America had 0.23. Even Europe had a positive growth rate of 0.12 (see Table 2). In other words - in the *past* 45 years Latin America grew twice as fast as it will grow in the next 30 years. We can also see that between 2025 and 2050 the United Nations Population Division assumes much slower population growth than during the next 30 years. While Africa, for instance, is projected to have a growth rate of 0.44 between 1995 and 2025, it should be only 0.26 between 2025 and 2050.

From a methodological point of few these growth rates for the *second* quarter of the next century are, of course, highly uncertain. But they show that the *critical* phase of world population growth is during the next three decades. If the world population will increase to only 9.3 billion people, then most of this growth will happen during the next 30 years. If the growth rates will *not* be down *significantly* by 2025 we will have a much larger population in 2050.

1.6 The ten countries which will contribute *most* to world population growth during the next 30 years are India, China, Pakistan, Nigeria, Ethiopia, Indonesia, United States of America, Bangladesh, Zaire and Iran - in that order!

According to the most recent UN population projection India will add more than 400 million to its population between 1995 and 2025 - China will grow by only 260 million (see Table 3). The next largest contributor to world population growth - surprisingly - is not Indonesia with its third largest population among developing countries, but Pakistan. Pakistan will grow by about 133 million between 1995 and 2025. An almost equal contribution to world population growth will probably come from Nigeria - 127 million. Perhaps unexpected, the next largest contributor to world population growth will be Ethiopia, which will add another 80 million people. Indonesia, on the other hand, will grow by "only" 78 million - which is only rank six in the "hit list" of contributors to world population growth. The United States will probably grow by 65 million and Bangladesh by 62 million. Few development experts would have put Zaire on a watch list for population problems. But the population in this Central African country is projected to grow by more than 60 million. The tenth largest contributor to world population growth will be Iran - with a population increase of almost 60 million between 1995 and 2025 (see Table 3).

1.7 India will out-grow China.

India has one of the oldest family planning programs. It started way back in the 1950s. The country's average fertility, however, declined only slowly. In the early 1950s both China and India had a Total Fertility Rate (TFR) of about 6 children per woman. But while China's TFR sharply fell to about 2.4 in 1990, it declined only slowly in India and was still above 4 children per woman in 1990. This relatively slow decline of fertility has built up a huge population momentum in India. The country's population structure is much "younger" than that of China. These young adults - born during the high growth period in the 1950s, 1960s and even 1970s - will have children in the near future. Even if fertility continues to decline to reproductive level by 2020 (as being assumed by the UN projections) the Indian population will probably increase to almost 1.6 billion by 2050 - slightly more than that of China (UN medium variant) (see Figure 3). However, India's population might become even much larger. If the average Total Fertility Rate would only decline to 2.6 (instead of 2.1) children per woman in 2020, the population would increase to about 1.9 billion (!) by 2050 (see high UN variant in Figure 3).

1.8 Nigeria and Pakistan: emerging population giants.

There are not many countries in the world where population projections are more difficult to believe than in Nigeria. If the latest UN projections are correct then our children (and the younger among us) will watch the emergence of an African population giant, well comparable to the most populous Asian nations. In 1950 the West-African country had a population of about 33 million; since then the population has more than tripled. The UN Population Division estimates that Nigeria's population in 1995 was about 112 million (please note that the UN does *not* revise their estimate according to the most recent Nigerian census, which was significantly lower. Obviously, the UN Population and Statistical Divisions do not consider this census accurate enough). Between now and the year 2050 the country's population will probably triple again and reach almost 339 million (see Figure 4). If that really happens we will have a ten-fold increase of a 33 million population within one century. This would have no historical precedence. Please note that we are talking about the *medium* variant UN projection. Based on the demographic parameters it would be not impossible if Nigeria's population would grow even faster.

There are other overwhelmingly Muslim populations with very high population growth rates, such as those of Saudi Arabia, Kuwait or the United Arab Emirates. But none of them is projected to have such a massive absolute increase of the population as Pakistan. In 1950 Pakistan had a population of about 40 million people - and was quite comparable in population size to Bangladesh (42 million), Brazil (54 million) or - for instance - Italy (39 million). Since then Pakistan's population has more than tripled and stood at 136 million in 1995. At that time Brazil was 159 million, Bangladesh 118 million and Italy 57 million. But the real population explosion in Pakistan will come during the next few decades. The population not only has a very large proportion of young men and women in reproductive age, but also still extremely high fertility - much higher, for instance, than in Bangladesh or Brazil. These young couples will produce a large number of children even if we assume, as in the UN medium variant, a decline of average fertility to reproductive level (of 2.1 children per woman) by 2020. Pakistan's population will be about 357 million by 2050 (according to the UN medium variant projection) - far larger than that of Bangladesh (218 million), Brazil (243 million) or, of course, Italy (42 million) (see Figure 4). However, it is (demographically) not impossible, that Pakistan's population increases even further to some 413 million by 2050 (UN high variant projection).

High fertility in the early 1950 was not the only reason for the exceptional population growth of Nigeria and Pakistan. There were other countries which had a similar or even higher level of fertility. Consider the case of Bangladesh and Thailand. The Total Fertility Rate in Bangladesh during the early 1970 was as high as in Nigeria or Pakistan and the initial population size was quite comparable. Yet Bangladesh is projected to have a population of "only" 220 million by 2050 (as compared to Nigeria's 339 million). Thailand is one of the Asian "success stories" in population control. The average TFR was as high as in Nigeria but declined sharply since the 1970s. As a result Thailand will have a very moderate population increase between now and 2050 of only some 14.7 million (see Figure 4).

1.9 The global balance of population has shifted significantly between 1950 and 1995. It will change even more dramatically between now and 2050.

Europe's share of the world population has sharply declined from 21.7 in 1950 to 12.8 percent in 1995. Africa's share, on the other hand, has increased from 8.9 to 12.7% (see Table 4). Today, both Europe and Africa are each home of about one eighth of the world population. This will change significantly in the future. Europe's share of the global population will shrink to about 6.8 percent in 2050. Africa's share will grow to 21.8 percent. Hence, one century of population growth will completely reverse Europe's and Africa's position: Europe's share of the global population in 2050 will be the same as that of Africa in 1950 - and vice versa. If the UN medium variant projections turn out to be correct (and there is no sign that they may be utterly wrong) we have to expect a dramatic change in the global balance of population: A much bigger share of the world population will live in Africa-South-of-the-Sahara. In only some 50 years Western Africa, for instance, will have the same population as *all* of Europe and Eastern Africa will have much more people than all countries of South America, the Caribbean and Oceania *combined.*

1.10 World-wide, the population will age.

During the next decades the world population structure will inevitably age. This is an unavoidable consequence of large birth cohorts during the 1950s and 1960s and the rapid fertility decline since the 1970s. In 2025 the "baby boomers" of the 1950s and 60s will be between 65 and 75 years of age. These large aging cohorts are followed by the relatively small "baby bust" generations of the worldwide fertility decline.

In 1950 there were only 131 million people of age 65 and older; in 1995 the number of elderly had tripled - it was estimated at 371 million. Between now and the year 2025 it will more than double again, and by 2050 we might have more than 1.4 billion elderly worldwide (see Table 5). In 1950 only 5.2 percent of the world population were of age 65 or more - today the percentage has already increased to 6.2 and by 2025 one out of ten people worldwide will be 65 years of age or more.

While currently population aging is most serious in Europe and Japan, Eastern Asia (China) will experience a dramatic increase in the proportion of elderly people by the middle of the next century. This is largely due to the country's success in family planning, which rapidly reduced the relative size of birth cohorts since the 1970s.

2. The Demographic Momentum

As we have demonstrated with the projections above there is almost no doubt that the world population will grow for quite some time. Of course we can imagine massive natural catastrophes, such as the world being hit by a huge meteor; we can also think about the emergence of a highly contagious lethal virus for which no cure or immunization can be found; or we could be frightened about a worldwide nuclear war that might result in sudden, non-reversible climate change - but short of these highly unlikely events almost nothing could stop the global population from increasing another few billion people. Why are we so sure about this?

- First, there is a driving force concealed in the "young" age structure of the world population that just cannot be switched off. Due to high fertility in the 1950s, 1960s and 1970s in many developing countries large numbers of women (and men) are currently entering reproductive age. The world is full of young adults that will have children. Even if each couple has a smaller number of children than their parents the total number of offsprings will be substantial. This "echo effect" of a high-fertility period in the past creates a "demographic momentum" which works against changes in reproductive behavior that favor smaller families.
- Second, it is highly unlikely that large populations will *instantly* change their reproductive behavior. Certain sections of a population, such as highly educated middle-class couples in urban areas, might adopt radical behavioral change almost overnight, but many developing countries still have large rural populations where fertility is linked to deep-rooted cultural values or social conditions and can decline only gradually over two or three generations. We must also take into account that the average fertility of a population is a composite measure which results from the reproductive behavior of several parent cohorts: these include couples which already have a certain number of children and can only reduce the number of additional offspring. Even in a country like China, where we have a highly controlled society and a most rigorous family planning program, it took 20 years to reduce average fertility from about 6 to 2.4 children. In India - according to UN projections - this process might take 60 years or more.

These two basic facts, which are well known among demographers, tend to slow down demographic change. They can produce a considerable time-lag between the first signs of a fertility decline and a slow down of population growth. In fact, it is quite typical for developing countries that the total number of births increases for one or even two decades, while the fertility (that is the average number of children per woman) already declines. Consider Figure 2 in which we have plotted global population growth together with the change in Total Fertility Rates (TFR) - as being derived from the 1996 round of UN Population Assessments and Projections. Please note that between 1950 and 1995 the chart is based on (estimates of) historical data, while from 1995 to 2050 both the total population and the TFR are projections. Globally, the TFR dropped from about 5 children per woman in 1950 to some 2.9 in 1995; during that same period world population more than doubled from 2.5 to 5.2 billion. The UN assumes a further steep decline of fertility to 2.1 children in 2050. During that period the world population will further increase to 9.3 billion people.

Between 1965 and 1995, while the TFR dropped significantly, the annual increase of the world population grew from about 65 to 85 million. In other words, more and more people were added to the global population, while couples had less and less children (see Figure 2).

These contrary trends become even more apparent when we plot *indices* of the Total Fertility Rate, the average annual increase of the population and the annual population growth rates. For the five-year period of 1950-55 the indices are set to 100 (see Figure 5). This "paradox" is simply a consequence of the fact that the increase in the number of parents outpaced the decline in fertility. In fact this situation will continue for some time. According to the most recent UN projections we will have a stable annual increase of about 80 million people until 2015 - only then will this increase gradually decline to about 47 million in 2050. By the middle of the next century the world population will still grow by about the same number of people as in 1950 - only the total number of people on the planet will be more than three times larger.

3. What do we *not* know about future population growth?

We know that fertility is declining almost everywhere. But we do *not* know how *fast* and to which *level* it will fall. There is not much indication that some Islamic countries, such as Pakistan or the Gulf states in Western Asia, will have *significantly* lower fertility in the near future. On the other hand there are signs that fertility is dropping even *faster* than expected in several other Asian and even African countries. This would result in a smaller world population than previously expected. Some researchers even believe that the global population could stabilize somewhat below 10 billion people in the long run (Lutz, 1996). Of course, this - to a large extent - is based on educated speculation, since it depends on assumptions about changes in reproductive behavior of people who are not even born today. There is great controversy among demographers whether these assumptions can be justified: some highly respected demographers, such as Nathan Keyfitz or Joel E. Cohen have argued that population projections are impossible beyond 10 or 15 years (Keyfitz, 1981; Cohen, 1995). Others have applied sophisticated methodologies such as probabilistic projections to calculate even very long-term projections (or scenarios) up to the year 2100 (Lutz, 1996). Those who have regularly conducted world population projections for more than 3 decades - such as the UN Population Division - can argue that their projections were fairly accurate if compared with the actual development (see Table 5).

The debate is still undecided. The only thing we know for sure is that there is **a high degree of uncertainty** for any projection that expands over more than 2 or 3 decades. One reason for this uncertainty is the high sensitivity of long-term projections to different assumptions on the *timing* and *speed* of the fertility decline. Even if all demographers would agree that fertility will come down to 2.1 children per woman in 2050 (which is the current UN assumption) a few years delay in this decline or a somewhat slower pace can make a difference for the world population of several *billion* people.

So far we have only talked about fertility. Of course this is a crude simplification. The real trouble begins when we take into account *future* changes in mortality. It was conventional wisdom among demographers for quite some time that mortality is not a very important issue when it comes to population projections: the developing countries would simply follow the trends in the developed world which were thought to have already stabilized. The lowest level of infant mortality would be around 10 deaths per 1000 life births and the *maximum* life expectancy would be about 82.5 years for men and 87.5 years for women (this was the UN assumption since their 1988 round of projections). However, things have changed unexpectedly:

- First, there is an *ongoing* decline in mortality in many developed countries. Especially adult and old-age mortality is falling quite significantly for both men and women. *Average* life expectancy in some of these populations (such as in Austria) has increased by about 2 years per decade during the 1970s, 1980s, and 1990s. A growing number of people are approaching ages that were previously considered a biological upper limit of the human life span. Micro-biological and genetic research has made a big step forward to understand (and possibly manipulate) the process of aging. It is not impossible that human life can be significantly expanded in the future by a combination of dietary practices, specific drugs and genetic therapy.
- Second, the expected across-the-board decline of mortality in the developing world has not materialized. While some developing countries, such as China, have seen a spectacular increase in life expectancy, others have lagged behind or, in fact, have even experienced recent declines. Especially for Africa-South-of-the-Sahara previous assumptions might have been overoptimistic - given the high prevalence of HIV-infection and AIDS, newly spreading tropical diseases and widespread violent conflicts.

Both trends have added **uncertainty** to our population projections - or rather made us aware of the uncertainty that was already there. While the prospects of increasing longevity among highly developed populations might only amplify their structural problems of aging, it is the new threat from AIDS and other causes in developing countries which could have a significant impact on world population growth. So far this is not in sight, but no one knows the future of the AIDS epidemic in India or other populous Asian countries. There is indication, for instance, that HIV infection is spreading rapidly in India and Thailand (US Bureau of the Census, 1996b).

The best strategy for reducing this uncertainty in population projections is to regularly revise the estimates, based on most recent demographic evidence. The UN Population Division has an excellent record for continuously fine-adjusting their estimates. Also, their early estimates from the 1960s seem to have been remarkably accurate for the year 2000 (see Table 5).

4. Estimating the balance of remaining land with cultivation potential

In this section we discuss to what extent the availability of land resources in the less developed countries can be expected to support the unprecedented population growth that will occur over the next 2 to 3 decades in many regions. The aim is to estimate the amount of land that from climatic, edaphic and topographic conditions may be adjudged the capability to sustain food crop production. Furthermore, we are interested in the relative quality of these lands, their broad geographic distribution as well as the major type of ecosystems that presently cover these areas.

The UN Food and Agriculture Organization (FAO), together with IIASA, has developed and widely applied a methodological framework for assessments of land productivity which originally was designed for use in agricultural development planning and natural resources management (FAO, 1978-81; FAO/IIASA, 1993; Fischer & van Velthuizen, 1996). A first assessment comparing crop production potential to minimum food requirements concluded that, overall, less developed regions would be able to feed their growing populations (FAO/IIASA/UNFPA, 1982). Agro-ecological zoning (AEZ) involves the inventory, characterization and classification of the land resources in a way meaningful for assessments of the potential of agricultural production systems. This characterization of land resources includes components of climate, soils and landform, basic for the supply of water, energy, nutrients and physical support to plants.

Crops require heat, light and water in varying amounts. The geographic distribution of crops is mainly governed by these climatic elements. Temperature, water and solar radiation are key climatic parameters which condition the net photosynthesis and allow crops to accumulate dry matter according to the rates and patterns which are specific to individual crop species. Crops have specific temperature requirements for their growth and development, and prevailing temperatures set the limits of crop performance when moisture (and radiation) requirements are met. Vice versa, when temperature requirements are met, the growth of a crop is largely dependent on how well the length of its growth cycle matches the period when water is available. In the AEZ approach, this has led to the concept of the length-of-growing-period (LGP) which is defined as the period (in days) during the year in which water availability and prevailing temperature can sustain crop growth.

Crop performance depends as well on the availability of nutrients in the soil, its capacity to store water and to provide mechanical support for crops. Therefore, agro-ecological zoning also includes an inventory of relevant soil and landform characteristics. The specific combinations of climatic, soil and terrain inventories form the basic land resources units of analysis.

Technical specifications (including management) within a socio-economic setting under which a specific crop is grown have been defined as land utilization types (LUT). Crop suitability assessments, in essence, are based on matching of crop specific adaptability characteristics and LUT ecological requirements with the attributes of individual land units.

4.1 *Estimating the extent of land with crop production potential*

To estimate the scope for expanding agriculture in response to population growth in developing countries and to assess the possible impact on forest ecosystems of increasing the extents of cultivated land a rather detailed assessment of land resources and land with rainfed cultivation potential was carried out at IIASA to provide inputs to a FAO study *World Agriculture: Towards 2010* (FAO, 1995). Some of the calculation steps were recently repeated using additional data and procedures, involving five main steps: quantifying land with cultivation potential; delineation of protected areas; subtracting land for habitation and infrastructure; overlaying of global ecosystems database; subtraction of land currently in cultivation.

The input for the evaluation of land with rainfed crop production potential consists of several geo-referenced data-sets: (a) the inventory of soil and land form characteristics from the FAO-UNESCO Soil Map of the World (SMW) (FAO, 1991); and (b) the inventory of climate regimes in which data on temperature, rainfall, relative humidity, wind speed and global radiation are used together with information on evapotranspiration, to characterize the thermal regimes and length of growing periods. The digitized inventories were overlaid to create a land resources inventory composed of several hundred thousands of land units, i.e., pieces of land of varying size with unique soil, land form and climate attributes.

Each land unit was tested for its suitability to grow any of the selected 21 major agricultural crops, under three levels of technology. (The crops are: millet, sorghum, maize, spring wheat, winter wheat, barley, bunded rice, upland rice, sweet potato, cassava, white potato, phaseolus bean, groundnut, soybean, cowpea, chickpea, oil palm, sugarcane, banana, olive and cotton.)

The estimated yields for each land unit, crop and technology alternative were then compared with those obtainable under the same major climate zone but without soil and terrain constraints, the latter yields being termed the maximum constraint-free yield. Any piece of land so tested, or part thereof, is classified as suitable for rainfed crop production if at least one of the crops could be grown under any one of the three technology alternatives with a yield of 20 percent or more of the maximum constraint-free yield for that management level. If more than one crop met this criterion, the amount of land classified as suitable was determined on the basis of the crop which could use the largest part of the land unit. Land units where none of the 21 crops met this criterion were classified as *not suitable* (NS) for rainfed crop production.

The land assessed as having potential for rainfed crop production is further classified into three broad suitability classes. When simulated crop yields were within 80 to 100 percent of maximum constraint-free yield the land was classified as *very suitable* (VS); *suitable* (S) when within 40 to 80 percent; and *marginally suitable* (MS) when assessed yield levels were between 20 to 40 percent. For presentation of results we consider five aggregate land classes, based on the combination of moisture conditions and crop suitability, as used by FAO (1988, 1995):

Low rainfall class (LOW):	dry semi-arid areas with length of growing periods of 75 to 120 days, all suitable soils;
Uncertain rainfall class (UNC):	moist semi-arid areas with LGP of 120 to 180 days and very suitable (VS) or suitable (S) land;
Good rainfall class (GOOD):	Sub-humid areas with LGP of 180 to 270 days and very suitable (VS) or suitable (S) land;
Problem area class (PROB):	includes VS, S and MS land in humid and per-humid regions (with LGP > 270 days), and moderately suitable (MS) land in LGPs of 120 to 270 days;
Naturally flooded class (NFL):	includes all suitable land where soils are classified as Fluvisols or Gleysols.

4.2 Delineation of protected areas

When land is indicated as legally defined protected (national parks, conservation forest and wildlife reserves) the respective land units are evaluated for cultivation potential but not considered available for agricultural expansion. In the study, the relevant data were available for 63 of the developing countries. Maps and inventories of National Parks, Conservation Forest and Wildlife Reserves (IUCN, 1990) were made available by the World Conservation and Monitoring Centre (Cambridge, UK) and provided to IIASA by the FAO. The data on protected areas are georeferenced and thus could be overlayed on the land resources inventory. These areas delineated in the GIS occupy a total of almost 400 million ha, i.e., about 6 percent of the total land area in developing countries (excluding China). Of this, around 200 million ha were assessed as having some potential for crop cultivation representing about 8 percent of the total extent with crop cultivation potential.

4.3 Subtraction of land for habitation and infrastructure

We have also attempted to broadly estimate the amount of land currently used for habitation and infrastructure occupying areas assessed as having cultivation potential (Heilig, 1994). Detailed information to estimate region specific land use for these purposes is scarce. The functional relationship parameterized in the study relies mainly on county-level data from China. It expresses per capita use of land for habitation and infrastructure in relation to population density. Examples of the parameterization are as follows: at 35 persons per km^2 the simulated requirement is 50 ha per 1000 people (hence 1.75 percent of the land), at 150 persons per km^2 the use is 26 ha per 1000 people (i.e., 3.9 percent of the land), at 675 persons per km^2 the use is 20 ha per 1000 persons (some 13.5 percent of the land), etc. Based on a georeferenced dataset of population density the respective subtraction of land for habitation and infrastructure purposes is carried out in each land unit.

4.4 Overlaying of global ecosystems database on the land with cultivation potential

To estimate the distribution of ecosystems among land assessed as having rainfed crop production potential a global ecosystems digital database (Kineman & Ohrenschall, 1992). was overlayed with the land resources data. The dataset is coded on a 10' by 10' latitude/longitude raster of grid-cells providing an adequate resolution for regional studies. 60 ecosystems classes are distinguished in the dataset which were aggregated into 12 aggregate land-cover categories as shown in Appendix A.

The GIS operation overlaying the results of the agro-ecological assessment with the global ecosystems database was tabulated by country to derive the distribution of ecosystems within land classes with cultivation potential. Tabulation of land resources both by detailed and aggregate classes has been carried out. For presentation here, the results were then further aggregated according to broader geographic regions.

4.5 Subtraction of land currently under cultivation

The steps previously described resulted in geographically explicit accounts of land with cultivation potential characterized in terms of major ecosystems classes. Finally, to subtract from these the land areas currently under cultivation two main data sources were relied upon: a digital copy of the accounts of cultivated land compiled by FAO (1995; data in Appendix 5), and the distribution of farmland ecosystem classes found in the global ecosystems database. It includes 10 ecosystems classes of pure or mixed agricultural use which were merged into 3 aggregated land-cover categories. We anticipate that activities currently underway by the International Geosphere-Biosphere Programme (IGBP) to develop high resolution global datasets on land cover and elevation (Townshend, 1992) will help to improve the accuracy of our estimation.

Regional land balances of areas with cultivation potential obtained by applying the 5-step procedure previously described are presented in Appendix B, a summary for all less developed countries is shown in Table 6 (for an explanation of table entries refer to Table 6B in Appendix B).

5. How well do land and water resources match the anticipated regional population momentum

As a first check to what extent the balance of remaining land with cultivation potential would enable the various regions to cope with the demographic trends outlined in sections 1 to 3, demand for arable land was estimated under crude assumptions for projected year 2030 and 2050 population levels. In the simplest case it is assumed that[1]: (a) the additional demand for cultivated land increases linearly with population; (b) only a fraction, overall in the order of 20 percent but varying with region, of the additional agricultural output needed will have to be met from expanding cultivated land. In specifying this fraction, we have broadly adopted the assumptions of FAO (1995) (see Table 7). For instance, in Sub-Saharan Africa about 30 percent of the

[1] Of course, both these assumptions can be contested with regard to their nature as well as the parameterization used.

contribution to total crop production increases is assumed to be derived from expansion of cultivated land. For land-scarce Asian regions this is assumed to be only about 5 percent.

Table 8 summarizes the calculations using population levels projected for years 2030 and 2050 (UN, 1997). The share of production increases not accounted for by expanding cultivated land would have to come from intensification, i.e., higher yields, reduced fallow periods and a larger number of crops per year. Table 8 compares, for groups of countries in less developed regions, the additional need for cultivated land estimated under these assumptions to the balance of land potentially available. Even under these very mild conditions the populous region of South-central Asia and the land-scarce Western Asia region are not likely to have enough suitable land resources to meet even only 5 to 10 percent of the required production increases from expansion of cultivated land, Western Africa reaching close to the limits.

Land cover change, in particular deforestation, has been identified as a key factor contributing to global environmental change (Turner et al., 1993). Alterations of the carbon pools, changes in albedo and the balance of sensible and latent heat fluxes, the impacts on total runoff and runoff speed, and the concern about loss of ecological complexity and biodiversity have prompted the international research community to focus their attention on the impacts of land-use and land cover change (Turner et al., 1995; Fischer et al., 1996). It is therefore of interest to assess the balance of land remaining when setting aside land with crop production potential which is currently covered by ecologically highly valued ecosystems such as forest or wetland ecosystems. If this condition were to be strictly applied, six out of eleven developing regions would not be able to meet the stipulated increases in cultivated land, as forests and wetlands cover on average about two thirds of the balance of land with cultivation potential.

A detailed discussion of water resources availability and future water use is beyond the scope of this paper. In the past, various studies have been devoted to the subject of water resources such as the work by Baumgartner & Reichel (1975), L'vovich (1979), Shiklomanov & Markova (1987), Falkenmark (1989), and Shiklomanov (1990). A comprehensive analysis and collection of data is contained in Gleick (1993). Kulshreshtha (1993) considers several scenarios of future water demand and supply at national level.

As a crude measure of regional vulnerability with respect to water resources, we look at the regional levels of annual renewable freshwater water resources available per capita, and their change with respect to altered population levels. Countries are grouped into three broad categories with regard to the availability of water resources. Water experts suggest that regions with an annual renewable freshwater water resource of less than 1000 m^3/cap/year should be regarded as water scarce. When water supply ranges between 1000 to 2000 m^3/cap/year water stress is likely to occur. Only at levels exceeding 2000 m^3/cap/year regions are considered to have abundant water supplies. Data reported by the World Resources Institute (WRI, 1996) and population levels projected by the UN (UN, 1997) were used to flag regions where population pressure may results in water stress as defined above. Table 9 shows results of such classification for both developed and developing regions. In 1995, three of the less developed regions, namely Northern Africa, Southern Africa, and Western Asia are considered to experience water scarcity or stress. By 2030 this number increases to six, adding Eastern Africa, South-central Asia and Eastern Asia. Western Africa would join the ranks of water stressed regions between 2030 to 2050.

6. Conclusions

In this paper we have reviewed what is known and expected about future population development. Regional differences in demographic change were presented and population increase was compared with estimates of land and water resources availability. From this analysis some key conclusions can be drawn:

- The 1996 UN Population Estimates and Projections indicate a 65 percent increase in world population between 1995 to 2050.
- Population numbers in developed regions will, in the aggregate, approximately remain at the current level. All the growth will occur in less developed countries, increasing their numbers by more than 80 percent.
- There is also a wide variation of projected population increases among less developed regions. The largest increases, in percentage terms, between 1995 to 2050 are projected for Sub-Saharan African regions, namely in Middle Africa (240%), Eastern Africa (215%) and Western Africa (205%). These are followed by Western Asia (130%) and Southern Africa (125%). In absolute terms, however, the largest increase will occur in South-central Asia, an addition of some 1.15 billion people during the projected 55 years.
- Most of the population growth will already occur until year 2030. While there are many uncertainties involved when projecting demographic changes to 2050 and beyond, the projection methods are fairly robust and show little variation when applied to the next 2 to 3 decades.
- An assessment of the extent of land with rainfed cultivation potential has concluded that land resources in less developed regions could allow crop production on some 2.5 billion hectares. An estimated 900 million hectares have been under cultivation at around 1990, leaving a balance of 1.6 billion hectares. Some 30 percent of these extents are adjudged only marginal suitability due to severe soil and landform limitations, excessive wetness conditions or drought hazard.
- The distribution of land resources is rather uneven. Of the 1.6 billion hectares of the balance of land with potential for rainfed crop production almost half (47%) is located in Latin America, some 45% in Africa, and only 8% in Asia.
- Overall, it is estimated that two thirds of the balance of land with rainfed cultivation potential is currently covered by various forest ecosystems, wetlands and mangroves. The respective percentages by region vary between 23% in Southern Africa to 89% in South-eastern Asia. For Latin America and Asia the estimated share of the balance of land with cultivation potential under forest and wetland ecosystems is about 70 percent, in Africa this is about 60%. If these were to be preserved, the remaining balance of land with some potential for rainfed crop cultivation would amount to 550 million hectares.
- In addition to the uneven spread of land and water resources time is an important factor as well. The rapid population growth during the next 3 decades will leave little time to develop land and water resources along a sustainable path.
- The regions which will experience the largest difficulties in meeting future demand for land resources and water, or alternatively have to cope with much increased dependency on external supplies, can clearly be identified from our analysis. These include foremost Western Asia, South-central Asia, and Northern Africa. A large stress on resources is to be expected also in many countries of Eastern, Western and Southern Africa (Heilig, 1996).

Recent initiatives to establish global monitoring and observation systems as well as national and international programmes to study the driving forces and impacts of land-use and land-cover changes will result in much improved information that will allow to assess the conditions and prospects for expanding food production more precisely than was possible here. Our analysis demonstrates that such understanding is of utmost importance and urgency.

Bibliography

Baumgartner, A. and E. Reichel. (1975). The world water balance. Vienna: R. Oldenburg Verlag.

Cohen, J.E. (1995). How many people can the earth support. New York (W.W. Norton).

Falkenmark, M., (1989). Water scarcity and food production in Africa. In D. Pimentel and C.W. Hall (eds.), Food and natural resources, New York, Academic Press.

FAO, (1978-81). *Report on the agro-ecological zones project.* Vol 3. Methodology and results for South and Central America. World Soil Resources Report 48/3. , Food and Agricultural Organization of the United Nations, Rome.

FAO, (1988). *World Agriculture Toward 2000, An FAO Study.* Edited by N. Alexandratos, Food and Agricultural Organization of the United Nations and J. Wiley & Sons.

FAO. (1991). The Digitized Soil Map of the World (Release 1.0). *World Soil Resources Report.* FAO, Rome.

FAO, (1995). *World Agriculture: Towards 2010, An FAO Study.* Edited by N. Alexandratos, Food and Agricultural Organization of the United Nations and J. Wiley & Sons.

FAO, (1996). FAOSTAT. Food and Agricultural Organization of the United Nations, Rome.

FAO/IIASA/UNFPA, (1982). *Potential population supporting capacities of lands in the developing world.* Technical Report on Project INT/513, FAO, Rome.

FAO/IIASA, (1993). *Agro-ecological assessments for national planning: the example of Kenya.* FAO Soils Bulletin 67, FAO, Rome.

Fischer, G., I. Ermoliev, M.A. Keyzer, and C. Rosenzweig, (1996). *On modeling the socioeconomic and biogeophysical driving forces of land-use and land-cover change: The IIASA land-use change mode.* WP-96-10, International Institute for Applied Systems Analysis, Laxenburg.

Fischer, G., and H.T. van Velthuizen, (1996). *Climate change and global agricultural potential project: A case study of Kenya.* WP-96-71, International Institute for Applied Systems Analysis, Laxenburg.

Gleick, P., (ed.) (1993). *Water in Crisis: A Guide to the World's Freshwater Resources.* Oxford University Press, Oxford.

Heilig, G.K. (1994). Neglected Dimensions of Global Land-Use Change: Reflections and Data. In: *Population and Development Review.* Vol. 20, No. 4, 831-859.

Heilig, G.K. (1996). How many people can be fed on Earth? In: Lutz, W. (Ed.): *The Future Population of the World. What can we assume today?* Revised and updated edition. Earthscan (London), 196-249.

IUCN. (1990). *United Nations List of National Parks and Protected Areas.* International Union for the Conservation of Nature and Natural Resources, Cambridge.

Keyfitz, N. (1981). The limits of population forecasting. In: Population and Development Review, Vol. 7, No. 4, 579-593

Kineman, J.J. & M.A. Ohrenschall. (1992). Global Ecosystems database Version 1.0 (on CD-ROM) Disc-A, Documentation manual. Key to *Geophysical Records Documentation* No. 27. USDOC/NOAA National Oceanic and Atmospheric Administration, Boulder, CO, USA.

Kulshreshtha, S.N. (1993). World Water Resources and Regional Vulnerability: Impact of Future Changes, *Research Report* RR-93-10. International Institute for Applied Systems Analysis, Laxenburg.

Lutz, W. (Ed.) (1996). The Future Population of the World. What Can We Assume Today? Revised Edition. London. (Earthscan Publications Ltd.)

L'vovich, M.I., (1979). World water resources and their future (English translation by R.L. Nace). Washington, DC: American Geophysical Union.

Shiklomanov, I., (1990). Global water resources. Nature and Resources **26**(3):34-43.

Shiklomanov, I., and O.L. Markova, (1987). Water availability and streamflow transfer problems over the world (in Russian). St. Petersburg: Gidrometeoizdat.

Townshend, J.R.G. (1992). Improved Global Data for Land Application: A Proposal for a New High Resolution Data Set. *IGBP Report* No. 20. International Geosphere-Biosphere Programme, Stockholm.

Turner II, B.L., R.H. Moss, and D.L. Skole. (1993). Relating Land Use and Global Land-Cover Change: A Proposal for an IGBP-HDP Core Project. *IGBP Report.* No. 24 and *HDP Report.* No. 5. International Geosphere-Biosphere Programme and the Human Dimensions of Global Environmental Change Programme, Stockholm.

Turner II, B.L., D.L. Skole, S. Sanderson, G. Fischer, L. Fresco and R. Leemans. (1995). Land-Use and Land-Cover Change Science/Research Plan. *IGBP Report.* No. 35 and *HDP Report.* No. 7. International Geosphere-Biosphere Programme and the Human Dimensions of Global Environmental Change Programme, Stockholm.

United Nations (to be published in 1997). World Population Prospects. The 1996 Revision. UN Population Division. New York Washington

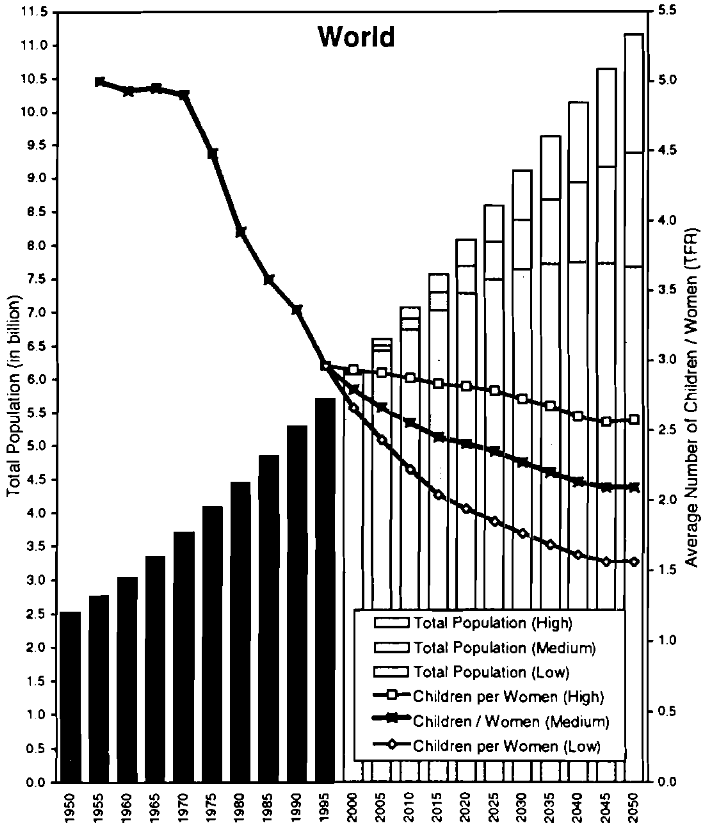
US Bureau of the Census (1996a). Trends and Patterns of HIV/AIDS Infection in Selected Developing Countries. Country Profile, June 1996. Washington, D.C. (Health Studies Branch, International Programs Center, Population Division, US Bureau of the Census, Research Note No. 22)

US Bureau of the Census (1996b). World Population Profile: 1966. With a Special Chapter Focusing on Adolescent Fertility in the Developing World., D.C. (Report prepared by Thomas M. McDevitt of the International Programs Center (IPC), Population Division, US Bureau of the Census, Report WP/96)

Vu, My T. (1985). World Population Projections, 1985. Short- and Long-Term Estimates by Age and Sex with Related Demographic Statistics. Baltimore and London (Published for the World Bank by The Johns Hopkins University Press)

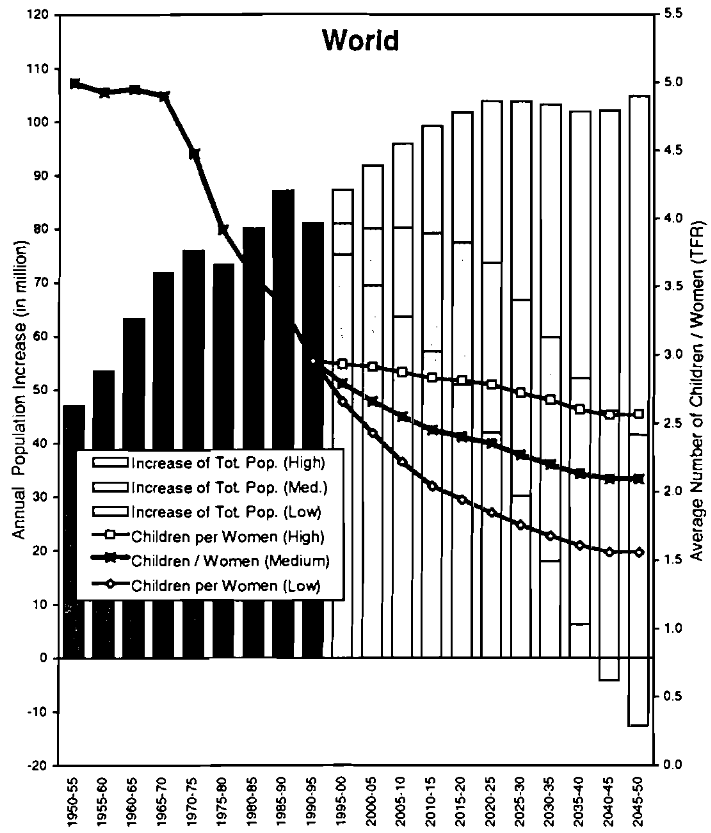
WRI, (1996). *World Resources 1996-97, A Guide to the Global Environment.* The World Resources Institute, Oxford University Press.

Figure 1: Total World Population, 1950-2050 (in billion) and Average Number of Children per Women (Total Fertility Rate). High, Medium and Low Variant UN Projections, 1996.



Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Figure 2: Average *Annual* World Population Increase (in million) and Average Number of Children per Women (Total Fertility Rate). High, Medium and Low Variant UN Projections, 1996.



Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 1: Total Population by Region in 1950, 1995, 2025 and 2050 (in 1000). Low, Medium and High Variant UN Projection, 1996.

	Historical Estimates		UN Projections, 1996					
			Low Variant		Medium Variant		High Variant	
	1950	1995	2025	2050	2025	2050	2025	2050
World total	**2,523,878**	**5,687,113**	**7,474,059**	7,662,248	**8,039,130**	9,366,724	**8,580,509**	**11,156,318**
More devel. regions	812,687	1,171,384	1,149,984	959,159	1,220,250	1,161,741	1,286,133	1,351,681
Less devel. regions	1,711,191	4,515,729	6,324,075	6,703,089	6,818,880	8,204,983	7,294,375	9,804,637
Africa	223,974	719,495	1,370,579	1,731,421	1,453,899	2,046,401	1,546,302	2,408,106
Eastern Africa	65,624	221,315	453,249	593,984	480,182	698,596	506,719	812,974
Middle Africa	26,316	83,271	181,841	252,289	187,525	284,821	200,438	336,396
Northern Africa	53,302	158,077	236,621	258,834	256,716	317,267	276,175	381,781
Southern Africa	15,581	47,335	78,449	90,256	82,901	106,824	87,335	124,900
Western Africa	63,151	209,498	420,419	536,058	446,574	638,892	475,634	752,055
Latin Am. & Carib.	**166,337**	**476,637**	**631,598**	**649,866**	**689,618**	**810,433**	**752,670**	**1,000,555**
Caribbean	17,039	35,686	44,778	45,478	48,211	56,229	51,224	65,827
Central America	36,925	123,474	175,438	189,415	189,143	230,425	206,032	282,729
South America	112,372	317,477	411,382	414,973	452,265	523,778	495,414	651,999
Northern America	171,617	296,645	336,398	301,140	369,016	384,054	393,598	451,503
Asia	1,402,021	**3,437,787**	**4,428,376**	**4,405,219**	**4,784,833**	**5,442,567**	**5,108,307**	**6,500,750**
Eastern Asia	671,156	1,421,314	1,572,978	1,374,217	1,695,469	1,722,380	1,785,553	1,999,209
South-eastern Asia	182,035	481,920	634,064	651,846	691,911	811,891	749,613	994,046
South-central Asia	498,583	1,366,866	1,944,779	2,057,954	2,100,034	2,521,304	2,256,712	3,053,930
Western Asia	50,247	167,686	276,556	321,202	297,420	386,992	316,429	453,566
Europe	**547,318**	**728,244**	**669,468**	**537,521**	**701,077**	**637,585**	**736,585**	**742,331**
Eastern Europe	219,296	310,506	271,948	215,673	284,170	255,955	303,706	311,048
Northern Europe	78,094	93,372	89,039	75,785	95,593	94,194	98,776	105,667
Southern Europe	109,012	143,377	131,939	102,990	137,196	119,887	142,603	135,502
Western Europe	140,916	180,988	176,542	143,072	184,118	167,550	191,500	190,115
Oceania	**12,612**	**28,305**	**37,640**	**37,081**	**40,687**	**45,684**	**43,047**	**53,073**
Australia/New Zeal.	10,127	21,427	26,380	24,235	28,809	30,557	30,561	35,495
Melanesia	2,095	5,814	9,636	11,040	10,150	12,972	10,655	15,036
Micronesia	153	481	811	928	857	1,097	905	1,285
Polynesia	237	583	813	879	871	1,059	926	1,257
Least dev. countr.	197,572	579,035	1,092,685	1,384,413	1,159,255	1,631,820	1,231,329	1,916,482

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 2: Population Increase (in 1000) and in Exp. Annual Growth Rate (in %) by Region between 1950-1995, 1995-2025, 2025-2050 and 1950-2050. UN Medium Variant Projection, 1996.

	Population Change & Annual Exponential Growth Rates							
	1950-1995		1995-2025		2025-2050		1950-2050	
	in 1000	in%	in 1000	in %	in 1000	in %	in 1000	in %
World Total	3,163,235	0.34	2,352,017	0.22	1,327,594	0.12	6,842,846	0.25
More Dev. Regions	358,697	0.15	48,866	0.03	-58,509	-0.04	349,054	0.07
Less Dev. Regions	2,804,538	0.41	2,303,151	0.26	1,386,103	0.14	6,493,792	0.30
Africa	495,521	0.49	734,404	0.44	592,502	0.26	1,822,427	0.42
Eastern Africa	155,691	0.51	258,867	0.49	218,414	0.28	632,972	0.45
Middle Africa	56,955	0.48	104,254	0.51	97,296	0.32	258,505	0.45
Northern Africa	104,775	0.46	98,639	0.30	60,551	0.16	263,965	0.34
Southern Africa	31,754	0.47	35,566	0.35	23,923	0.19	91,243	0.36
Western Africa	146,347	0.50	237,076	0.48	192,318	0.27	575,741	0.44
Latin Am. & Carib.	310,300	0.44	212,981	0.23	120,815	0.12	644,096	0.30
Caribbean	18,647	0.31	12,525	0.19	8,018	0.12	39,190	0.23
Central America	86,549	0.51	65,669	0.27	41,282	0.15	193,500	0.35
South America	205,105	0.44	134,788	0.22	71,513	0.11	411,406	0.29
Northern America	125,028	0.23	72,371	0.14	15,038	0.03	212,437	0.15
Asia	2,035,766	0.38	1,347,046	0.21	657,734	0.10	4,040,546	0.26
Eastern Asia	750,158	0.31	274,155	0.11	26,911	0.01	1,051,224	0.18
So.Eastern Asia	299,885	0.41	209,991	0.23	119,980	0.12	629,856	0.28
So.Central Asia	868,283	0.42	733,168	0.27	421,270	0.14	2,022,721	0.31
Western Asia	117,439	0.51	129,734	0.36	89,572	0.20	336,745	0.39
Europe	180,926	0.12	-27,167	-0.02	-63,492	-0.07	90,267	0.03
Eastern Europe	91,210	0.15	-26,336	-0.06	-28,215	-0.08	36,659	0.03
Northern Europe	15,278	0.07	2,221	0.01	-1,399	-0.01	16,100	0.04
Southern Europe	34,365	0.11	-6,181	-0.03	-17,309	-0.10	10,875	0.02
Western Europe	40,072	0.10	3,130	0.01	-16,568	-0.07	26,634	0.03
Oceania	15,693	0.34	12,382	0.23	4,997	0.09	33,072	0.24
Aust.-N. Zeal.	11,300	0.31	7,382	0.19	1,748	0.04	20,430	0.21
Melanesia	3,719	0.43	4,336	0.35	2,822	0.19	10,877	0.34
Micronesia	328	0.48	376	0.36	240	0.19	944	0.37
Polynesia	346	0.38	288	0.25	188	0.15	822	0.28
Least Dev. Count.	381,463	0.45	580,220	0.44	472,565	0.26	1,434,248	0.40

Note: The exponential growth rate was calculated with the formula: $r = (\log(Pn / Po)) / n \log e$

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 3: The 10 Countries with the Highest Population Increase between 1950-1995, 1995-2025, 2025-2050 and 1950-2050. UN Medium Variant Projection, 1996.

Past Population Increase, 1950-1995

	(in 1000)
China	665,464
India	571,444
Indonesia	117,922
United States of America	109,302
Brazil	105,040
Pakistan	96,744
Nigeria	78,786
Bangladesh	76,446
Mexico	63,408
Iran (Islamic Republic of)	51,452

Projected Population Increase, 1995-2025

	(in 1000)
India	401,196
China	260,206
Pakistan	132,647
Nigeria	126,676
Ethiopia	79,884
Indonesia	77,785
United States of America	65,366
Bangladesh	61,751
Zaire	60,472
Iran (Islamic Republic of)	59,886

Projected Population Increase, 2025-2050

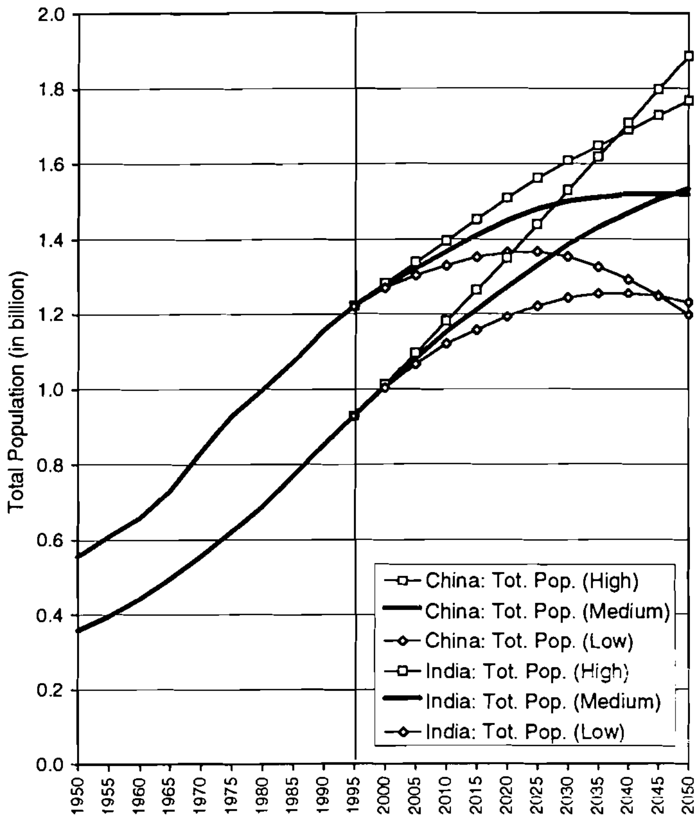
	(in 1000)
India	173,982
Nigeria	80,945
Pakistan	72,642
Ethiopia	62,534
Zaire	47,987
China	40,372
Indonesia	36,802
Iran (Islamic Republic of)	34,993
Bangladesh	32,585
Brazil	23,143

Centennial Population Increase, 1950-2050

	(in 1000)
India	1,175,113
China	961,904
Pakistan	317,840
Nigeria	305,575
Indonesia	238,726
Ethiopia	194,298
United States of America	189,730
Brazil	189,284
Bangladesh	176,405
Iran (Islamic Republic of)	153,356

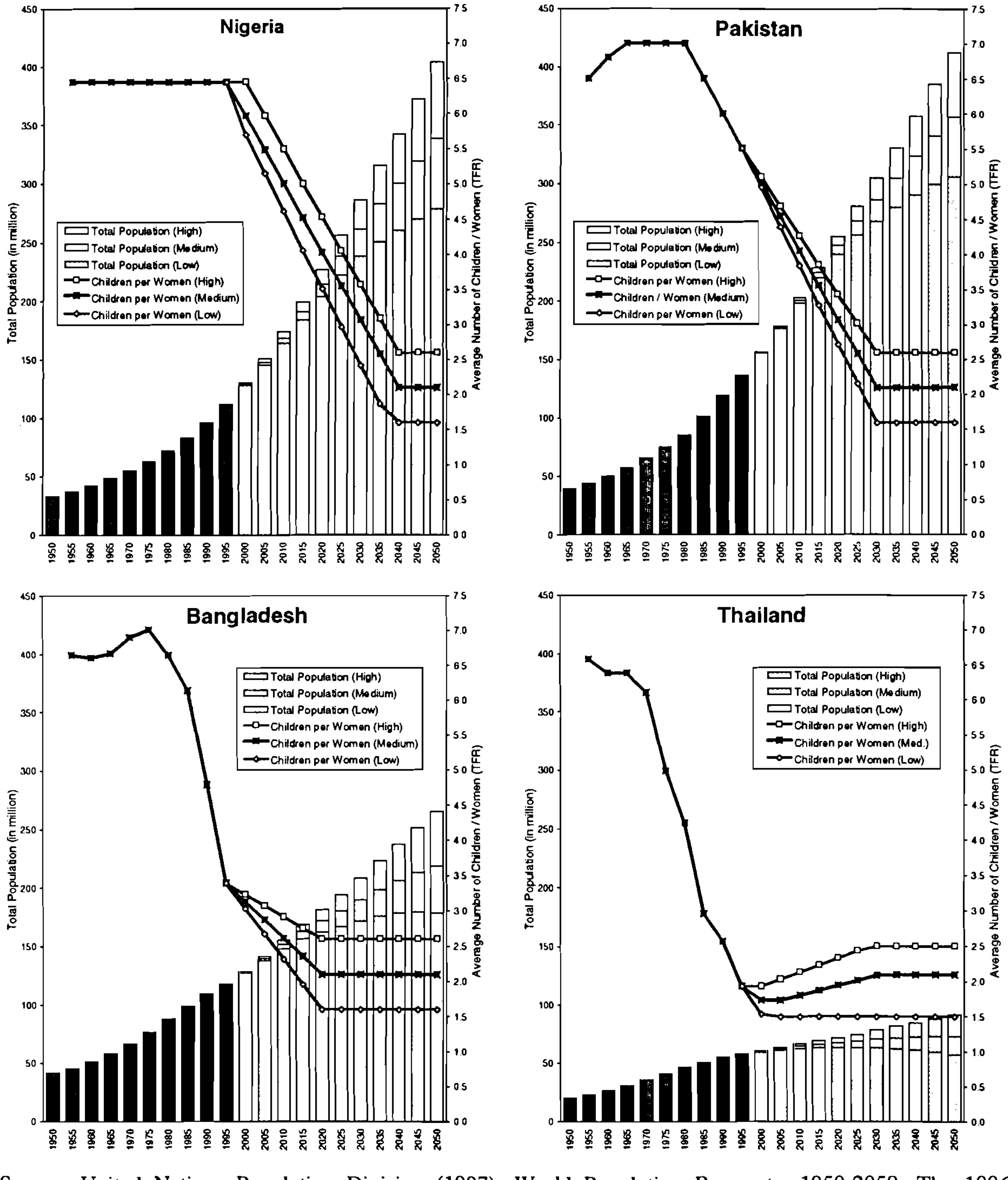
Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Figure 3: China and India: Total Population 1950-2050 (in billion). Low, Medium and High Variant UN Projection, 1996.



Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Figure 4: Nigeria, Pakistan, Bangladesh and Thailand: Total Population 1950-2050 (in million) and Average Number of Children per Women (Total Fertility Rate). High, Medium and Low Variant UN Projections, 1996. (All Chart have the same scales)



Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 4: Total Population (in 1000) and Proportion of Global Population by Region (in %), 1950, 1995, 2025 and 2050. Medium Variant UN Projection, 1996.

	Total Population (in 1000)				Percentage of World Pop.			
	1950	1995	2025	2050	1950	1995	2025	2050
World Total	2,523,878	5,687,113	8,039,130	9,366,724	100.0	100.0	100.0	100.0
More Dev. Regions	812,687	1,171,384	1,220,250	1,161,741	32.2	20.6	15.2	12.4
Less Dev. Regions	1,711,191	4,515,729	6,818,880	8,204,983	67.8	79.4	84.8	87.6
Africa	223,974	719,495	1,453,899	2,046,401	8.9	12.7	18.1	21.8
Eastern Africa	65,624	221,315	480,182	698,596	2.6	3.9	6.0	7.5
Middle Africa	26,316	83,271	187,525	284,821	1.0	1.5	2.3	3.0
Northern Africa	53,302	158,077	256,716	317,267	2.1	2.8	3.2	3.4
Southern Africa	15,581	47,335	82,901	106,824	0.6	0.8	1.0	1.1
Western Africa	63,151	209,498	446,574	638,892	2.5	3.7	5.6	6.8
Latin Am. & Carib.	166,337	476,637	689,618	810,433	6.6	8.4	8.6	8.7
Caribbean	17,039	35,686	48,211	56,229	0.7	0.6	0.6	0.6
Central America	36,925	123,474	189,143	230,425	1.5	2.2	2.4	2.5
South America	112,372	317,477	452,265	523,778	4.5	5.6	5.6	5.6
Northern America	171,617	296,645	369,016	384,054	6.8	5.2	4.6	4.1
Asia	1,402,021	3,437,787	4,784,833	5,442,567	55.6	60.4	59.5	58.1
Eastern Asia	671,156	1,421,314	1,695,469	1,722,380	26.6	25.0	21.1	18.4
So.Eastern Asia	182,035	481,920	691,911	811,891	7.2	8.5	8.6	8.7
So.Central Asia	498,583	1,366,866	2,100,034	2,521,304	19.8	24.0	26.1	26.9
Western Asia	50,247	167,686	297,420	386,992	2.0	2.9	3.7	4.1
Europe	547,318	728,244	701,077	637,585	21.7	12.8	8.7	6.8
Eastern Europe	219,296	310,506	284,170	255,955	8.7	5.5	3.5	2.7
Northern Europe	78,094	93,372	95,593	94,194	3.1	1.6	1.2	1.0
Southern Europe	109,012	143,377	137,196	119,887	4.3	2.5	1.7	1.3
Western Europe	140,916	180,988	184,118	167,550	5.6	3.2	2.3	1.8
Oceania	12,612	28,305	40,687	45,684	0.5	0.5	0.5	0.5
Aust.-N. Zeal.	10,127	21,427	28,809	30,557	0.4	0.4	0.4	0.3
Melanesia	2,095	5,814	10,150	12,972	0.1	0.1	0.1	0.1
Micronesia	153	481	857	1,097	0.0	0.0	0.0	0.0
Polynesia	237	583	871	1,059	0.0	0.0	0.0	0.0
Least Dev. Count.	197,572	579,035	1,159,255	1,631,820	7.8	10.2	14.4	17.4

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 7: Sources of growth in crop production and in harvested area, in developing countries, excluding China (%).

	Crop production				Harvested land	
	1970–90 Contribution of increases in:		1988/90–2010 Contribution of increases in:		1988/90–2010 Contribution of increases in:	
	yields	harvested land	yields	harvested land	arable land	cropping intensity
Developing countries	69	31	66	34	62	38
Africa (sub-Saharan)	53	47	53	47	64	36
Near East / North Africa	73	27	71	29	31	69
East Asia	59	41	61	39	82	18
South Asia	82	18	82	18	22	78
Latin America & Caribbean	52	48	53	47	60	40

Source: FAO (1995), Table 4.8, p.170.

Table 8: A simple balance of cultivated land in year 2050 (1000 ha)

Region	Cultivated land in 1990	Total balance	Share in Forest & Wetlands	Balance excluding Forest & Wetlands	% of production increase from land	Additional cultivated land required in 2050
Central America & Caribbean	36920	51966	0.80	10289	20	14603
South America	152965	710775	0.69	221762	30	82107
LATIN AMERICA	**189885**	**762740**	**0.70**	**232051**	**28**	**96710**
Eastern Africa	62860	185435	0.70	56558	30	68015
Middle Africa	43137	338398	0.75	86292	30	52478
Northern Africa	40409	67093	0.26	49380	15	13513
Southern Africa	15849	28062	0.23	21636	30	12031
Western Africa	90328	103057	0.36	65654	30	95666
AFRICA	**252583**	**722046**	**0.61**	**279719**	**29**	**241703**
Western Asia	36831	8674	0.92	668	10	9991
South-eastern Asia	82404	63610	0.89	7081	25	37837
South-central Asia	205614	11443	0.54	5218	5	20939
Eastern Asia	131376	43588	0.50	21794	5	8636
ASIA	**456225**	**127316**	**0.73**	**34741**	**10**	**65782**
DEVELOPING	**899795**	**1612101**	**0.66**	**546511**	**21**	**424194**

Source: Calculation by authors based on FAO (1995).

Table 5: Total Number (in 1000) and Proportion of Elderly (in percent of total population) by Region in 1950, 1995, 2025 and 2050. UN Medium Variant Projection, 1996.

	Population Age 65+ (in 1000)				Population Age 65+) As % of Total Population			
	1950	1995	2025	2050	1950	1995	2025	2050
World Total	130,669	370,707	801,929	1,415,924	5.2	6.5	10.0	15.1
More Dev. Regions	64,052	157,950	246,503	287,373	7.9	13.5	20.2	24.7
Less Dev. Regions	66,617	212,757	555,427	1,128,551	3.9	4.7	8.1	13.8
Africa	7,058	22,702	61,211	161,408	3.2	3.2	4.2	7.9
Eastern Africa	1,915	6,121	15,601	46,282	2.9	2.8	3.2	6.6
Middle Africa	999	2,606	6,236	17,220	3.8	3.1	3.3	6.0
Northern Africa	1,844	6,104	17,749	42,302	3.5	3.9	6.9	13.3
Southern Africa	565	2,014	5,299	12,112	3.6	4.3	6.4	11.3
Western Africa	1,736	5,856	16,326	43,491	2.7	2.8	3.7	6.8
Latin Am. & Carib.	6,220	24,171	66,425	135,362	3.7	5.1	9.6	16.7
Caribbean	760	2,376	5,214	9,233	4.5	6.7	10.8	16.4
Central America	1,498	5,123	15,815	36,968	4.1	4.1	8.4	16.0
South America	3,963	16,671	45,395	89,161	3.5	5.3	10.0	17.0
Northern America	14,102	37,080	68,367	82,550	8.2	12.5	18.5	21.5
Asia	57,384	183,427	458,581	863,449	4.1	5.3	9.6	15.9
Eastern Asia	29,978	96,559	225,266	345,838	4.5	6.8	13.3	20.1
So.Eastern Asia	6,774	20,712	56,393	124,734	3.7	4.3	8.2	15.4
So.Central Asia	18,428	58,757	155,694	345,205	3.7	4.3	7.4	13.7
Western Asia	2,204	7,399	21,229	47,671	4.4	4.4	7.1	12.3
Europe	44,981	100,620	141,764	164,798	8.2	13.8	20.2	25.8
Eastern Europe	14,287	38,201	50,967	59,786	6.5	12.3	17.9	23.4
Northern Europe	8,045	14,343	19,323	21,645	10.3	15.4	20.2	23.0
Southern Europe	8,303	20,913	30,810	37,085	7.6	14.6	22.5	30.9
Western Europe	14,347	27,163	40,665	46,282	10.2	15.0	22.1	27.6
Oceania	930	2,724	5,601	8,384	7.4	9.6	13.8	18.4
Aust.-N. Zeal.	839	2,504	4,948	6,717	8.3	11.7	17.2	22.0
Melanesia	82	182	532	1,375	3.9	3.1	5.2	10.6
Micronesia	3	15	52	126	2.0	3.1	6.1	11.5
Polynesia	6	24	70	165	2.5	4.1	8.0	15.6
Least Dev. Count.	6,521	17,658	45,543	124,915	3.3	3.0	3.9	7.7

Source: United Nations Population Division (1997): World Population Prospects, 1950-2050. The 1996 Edition. Annexes I and II. New York

Table 6: Balance of land with rainfed crop production potential in less developed regions

	Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total with rainfed cultivation potential 1000 ha	% of Total
Gross	161997	361849	645013	1232641	357708	2759207	100.0
Protected	7526	19204	44691	100462	29334	201217	7.3
Habitation 90	4038	10801	15275	23643	9672	63430	2.3
Net	150433	331844	585046	1108537	318702	2494561	90.4
Cultivated	87565	154757	267084	262694	90571	862671	31.3
Balance	62868	177087	317962	845843	228131	1631890	59.1
% Forest&Wetland	34	45	58	71	75	65	31.1
Foret&Wetland	21493	79311	185409	599190	170552	1055956	64.7
Other	41375	97775	132553	246652	57579	575933	35.3

Source: Calculation by authors based on FAO (1995)

Table 9: Annual renewable water resources (m^3/person/year)

Region	1995	2030	2050
USA + Canada	18141	14386	14012
Eastern Europe	2403	2586	2749
Northern Europe	10858	10619	10771
Southern Europe	3580	3823	4287
Western Europe	2178	2170	2355
Russian Federation	28769	33400	37361
Japan	4374	4611	4993
Australia & New Zealand	31269	22826	21926
Caribbean	2806	1989	1779
Central America	7919	4908	4243
South America	30019	20267	18199
Eastern Africa	2351	882	745
Middle Africa	23563	9371	6885
Northern Africa	546	318	272
Southern Africa	1304	702	578
Western Africa	4966	2121	1628
Western Asia	1850	940	769
South-eastern Asia	10883	7256	6460
South-central Asia	3032	1879	1641
Eastern Asia	2282	1854	1834
Central Asia	4881	3353	2966

Source: Data compiled by authors based on WRI (1996) and UN (1997).

Appendix 1: Global ecosystems database (dataset WE1.4D)

The first column indicates the global ecosystems class (Kineman&Ohrenschall, 1992), the second column the aggregation index used in the study. Class levels not listed are not used in the classification.

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# WORLD ECOSYSTEMS (WE1.4D)
NR IA P NAME    EXPLANATION
 0 11 8 WAT     Waters, including ocean and inland waters
 1 10 6 CCX     City complexes
 2  2 3 SSG     Short or sparse grass/shrub of semiarid climates
 6  4 4 TBE     Temperate/tropical montane broadleaf evergreen forest
 8  1 9 DMB     Desert, mostly bare stone, clay or sand
16  3 3 BES     Broadleaf evergreen scrub (commonly with #46 and #47)
17 11 9 ICE     Antarctic ice, land or grounded shore ice
20  4 8 SRC     Snowy, rainy coastal conifer
21  4 8 MBC     Main boreal conifers
22  4 7 SNB     Snowy non-boreal conifer forest
23  4 6 CDF     Conifer/deciduous, snow persisting in winter
24  4 4 TBC     Temperate broadleaf/conifer forest: with deciduous and/or
                evergreen hardwood trees
25  4 6 SDF     Temperate -deciduous forest, snow persisting in winter
26  4 4 TBF     Temperate broadleaf forest: deciduous, semideciduous
27  4 6 NSC     Non-snowy conifer forest
28  4 7 TMC     Tropical montane complexes (tree & other)
29  4 5 TBS     Tropical broadleaf seasonal forest, with dry or cool season
30 15 1 CFS     Cool farmland & settlements
31 15 1 MFS     Mild/hot farmland & settlements
32  4 4 RGD     Rain-green (drought deciduous) forest
33  4 4 TRF     Tropical rainforest
36 16 1 PRA     Paddy rice and associated lands (part anaerobic)
37 16 1 WCI     Warm/hot crops with extensive irrigation
38 16 1 CCI     Cool crops with irrigation (variable extent)
39 16 1 CCP     Cold crops, pasture, irrigation
40  2 5 CGS     Cool (snowy) grass/shrub (including much 2)
41  2 3 MGS     Mild/warm/hot grass/shrub
42  2 6 CSM     Cold steppe/meadow +/- larch, scrub
43  2 2 SGW     Savanna/grass, seasonal woods; savanna belts
44  8 6 MBF     Mire, -cold peatland: sphagnum, grass-like and/or dwarf
                shrub
45  8 6 MOS     Marsh or other swamp (warm-hot) salty/freshwater marsh,
                thicket
46  3 3 MES     Mediterranean evergreen tree/scrub (winter rainfall)
47  3 4 DHS     Dry or highland scrub/tree (juniper, etc.)
48  4 4 DEW     Dry evergreen woodland or low forest (mainly Australia, S.
                America)
49 13 7 HVI     Hot-mild volcanic 'islands' (variable veg.)
50  1 9 SDB     Sand desert, partly blowing
51  1 6 SDS     Semidesert/desert scrub/succulent/sparse grass
52  1 7 CSS     Cool/cold shrub semidesert/steppe (sagebrush ...)
53 12 9 TUN     Tundra (polar, alpine)
54  4 4 TER     Temperate evergreen rainforest (major forest and woodland)
55 14 3 SFW     Snowy field/woods complex
56 14 3 FFR     Forest/field complex with regrowth after disturbances
57 14 4 SFF     Snowy forest/field, commonly openings are pasture and/or
                mires
58 14 2 FWG     Field/woods with grass and/or cropland
59  3 7 STW     Succulent and thorn woods
60 12 6 SDT     Southern dry taiga (and other aspen/birch, etc.)
61 12 7 LT      Larch taiga with deciduous conifer
62 12 6 NMT     Northern or maritime taiga/tundra
63 12 4 WTM     Wooded tundra margin (or mt. scrub, meadow)
64  8 5 HMW     Heath and moorland, wild or artificial (grazed)
65 13 5 CNW     Coastal: NW quadrant near most land
66 13 5 CNE     Coastal: NE quadrant near most land
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67 13 5 CSE    Coastal: SE quadrant near most land
68 13 5 CSW    Coastal: SW quadrant near most land
69 11 9 PDL    Polar desert with rock Lichens
70 11 9 GLA    Glaciers (other polar and alpine)
71  1 8 SSF    Salt/soda flats (playas, lake flats rarely wet)
72  9 8 MSM    Mangrove swamp/mudflat (Africa only)
73 13 6 ISL    Islands and shore waters in oceans and/or lakes
74 13 8 WAT    Water (water/land complex)
75 11 9 UND    Not defined

# AGGREGATE ECOSYSTEMS CLASSES
 1 DESERT      Cold and hot deserts, bare land, salt flats, etc.
 2 GRASS       Various types of grass and shrub land
 3 SHR/FO......Various types of scrubs and woodland
 4 FOREST......Various types of evergreen and deciduous forests
 8 SWAMP.......Mires, marshes, swamps, heath and moorland
 9 MANGR.......Mangrove swamps
11 WAT/GL......Water, glaciers, antarctic ice, polar deserts
12 TND/TG......Various tundra and taiga areas
13 COASTL......Coastal areas
14 FRM/FO......Various farm/forest classes
15 FRM-D.......Dryland farming areas
16 FRM-IR......Irrigated farmland areas
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Appendix 2: Balance of land with cultivation potential

Explanations to Table 6 and Table 6B:

For estimating the balance of remaining land with crop production potential we started by assessing the extents of land where climate, soils and landform were sufficiently suitable for cultivation of at least one major crop (labeled 'Gross'), subtracting from these land units areas under legal protection (shown as 'Protected'). Land required for habitation and infrastructure is estimated using 1990 population levels (shown as 'Habit 90'), and by subtracting we form the net amount of land with cultivation potential (shown as 'Net'). From this we subtract land known to be used for agriculture (shown as 'Cultivated'. The data are from FAOSTAT (FAO, 1996) and FAO's AT2010 (FAO, 1995) study; data for China have been compiled by the IIASA Land-Use Change Project. This allows to form the balance of land with rainfed crop production potential which is not yet under such use (shown as 'Balance'). The next task was to identify the amount of forest and wetland ecosystems (i.e., aggregate ecosystems classes 4, 8 and 9) within this balance. To achieve this, the result from overlaying the Global Ecosystems database (Kineman&Ohrenschall, 1992) onto the land resources inventory was applied. The meaning of the respective rows in Table 6 and Table 6B is the following:

% Forest & Wetland ... percentage of forest and wetland ecosystems classes in respective land class
Forest & Wetland........ extent of forest and wetland in the balance of each land class
Other .... extent of other ecosystems classes in each land class

For instance, in South America some 714,097 thousand ha of land with cultivation potential are assessed as being still available out of a total of 963,525 thousand ha, i.e., 74.1 percent of the total land with cultivation potential is currently not used for crop cultivation. More than two thirds of this, 68.8 percent, are classified as forest or wetland in the global ecosystems database.

Table 6B: Estimated balance of land with rainfed cultivation potential (in 1000 ha)

CENTRAL AMERICA & CARIBBEAN		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	1819	20704	32472	30645	8691	94331
	Protected	3	485	1096	2582	1043	5208
	Habit. 90	33	469	830	587	153	2073
	Net	1783	19750	30546	27477	7494	87050
	Cultivated	1171	7473	13940	10630	835	34049
	Balance	612	12277	16606	16847	6659	53001
	% Forest & Wetland	43	71	82	83	79	80
	Forest & Wetland	268	8576	13889	14667	5107	42506
	Other	344	3701	2717	2180	1553	10494

SOUTH AMERICA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	14096	38835	150551	633066	126979	963525
	Protected	481	1536	9241	68295	12495	92048
	Habit. 90	222	596	1488	3604	745	6655
	Net	13393	36702	139821	561167	113739	864822
	Cultivated	5409	15450	67234	53726	8906	150725
	Balance	7984	21252	72587	507441	104833	714097
	% Forest & Wetland	29	34	50	72	76	69
	Forest & Wetland	2276	7222	36197	366028	79279	491002
	Other	5708	14031	36391	141412	25554	223095

EASTERN AFRICA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	26078	70571	115022	54832	30540	297042
	Protected	4027	9680	14980	5862	6607	41155
	Habit. 90	403	1164	1973	1068	473	5081
	Net	21647	59727	98069	47903	23460	250807
	Cultivated	8394	15323	25852	10687	2579	62835
	Balance	13253	44404	72217	37216	20881	187972
	% Forest & Wetland	44	75	72	71	61	70
	Forest & Wetland	5778	33473	52121	26583	12778	130734
	Other	7475	10931	20096	10632	8103	57238

MIDDLE AFRICA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	7611	27700	105295	205781	63727	410113
	Protected	410	1029	6053	10031	5635	23157
	Habit. 90	42	190	821	2027	537	3616
	Net	7160	26481	98421	193722	57556	383340
	Cultivated	1423	5711	13204	21893	906	43137
	Balance	5737	20770	85217	171829	56650	340203
	% Forest & Wetland	14	19	62	84	92	75
	Forest & Wetland	817	3886	53259	143658	51952	253572
	Other	4919	16885	31958	28172	4698	86632

Table 6B: Estimated balance of land with rainfed cultivation potential (cont.)

NORTHERN AFRICA	Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
Gross	20927	35583	24375	9865	16641	107390
Protected	61	525	515	310	382	1793
Habit. 90	279	436	477	132	206	1530
Net	20587	34622	23382	9423	16053	104067
Cultivated	14695	8397	8285	2215	2619	36211
Balance	5892	26225	15097	7208	13434	67856
% Forest & Wetland	28	12	40	41	30	26
Forest & Wetland	1677	3232	6067	2945	3979	17900
Other	4215	22992	9030	4263	9456	49956

SOUTHERN AFRICA	Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
Gross	14173	11653	8118	9509	1774	45227
Protected	878	36	0	6	236	1157
Habit. 90	54	9	18	20	4	105
Net	13241	11607	8100	9483	1534	43965
Cultivated	2608	6036	4222	2964	20	15850
Balance	10633	5571	3878	6519	1514	28115
% Forest & Wetland	33	8	27	9	53	23
Forest & Wetland	3502	452	1055	613	808	6430
Other	7131	5119	2823	5906	706	21685

WESTERN AFRICA	Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
Gross	32118	50921	59786	56630	12358	211812
Protected	1072	3084	3631	2641	394	10821
Habit. 90	524	1168	1375	1632	384	5084
Net	30523	46669	54780	52357	11580	195908
Cultivated	20837	19790	20021	25169	4495	90312
Balance	9686	26879	34759	27188	7085	105596
% Forest & Wetland	12	31	23	63	51	36
Forest & Wetland	1164	8329	7869	17143	3581	38086
Other	8521	18549	26890	10045	3504	67509

WESTERN ASIA	Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
Gross	12245	12740	7411	6255	4920	43571
Protected	0	0	0	0	0	0
Habit. 90	310	375	282	185	134	1285
Net	11935	12365	7129	6070	4787	42286
Cultivated	8425	10093	6870	6673	1122	33183
Balance	3510	2272	259	-603	3665	9103
% Forest & Wetland	100	85	88	90	89	92
Forest & Wetland	3510	1937	227	-545	3275	8405
Other	0	335	32	-58	390	698

Table 6B: Estimated balance of land with rainfed cultivation potential (cont.)

SOUTH-CENTRAL ASIA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	31756	84999	51595	29720	23761	221830
	Protected	594	1652	1860	831	359	5295
	Habit. 90	2138	6147	3947	2165	2468	16865
	Net	29023	77200	45789	26725	20934	199670
	Cultivated	24569	63052	45926	26279	22779	182605
	Balance	4454	14148	-137	446	-1845	17065
	% Forest & Wetland	31	62	86	66	58	54
	Forest & Wetland	1401	8782	-118	293	-1079	9279
	Other	3053	5366	-20	153	-766	7786

EASTERN ASIA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	11	368	47109	108528	33329	189346
	Protected	0	0	0	0	0	0
	Habit. 90	0	10	2077	9143	3168	14398
	Net	11	358	45032	99385	30162	174948
	Cultivated	3	1083	44479	58605	27190	131360
	Balance	8	-725	553	40780	2972	43588

SOUTH-EAST ASIA		Low rainfall area (LOW) 1000 ha	Uncertain rainfall area (UNC) 1000 ha	Good rainfall area (GOOD) 1000 ha	Problem area (PROB) 1000 ha	Gleysols and Fluvisols (NFL) 1000 ha	Total rainfed cultivation potential 1000 ha
	Gross	1165	7776	43280	87811	34988	175019
	Protected	0	1179	7317	9904	2183	20582
	Habit. 90	34	235	1987	3081	1402	6738
	Net	1131	6363	33976	74826	31403	147699
	Cultivated	31	2349	17051	43853	19120	82404
	Balance	1100	4014	16925	30973	12283	65295
	% Forest & Wetland	100	85	88	90	89	89
	Forest & Wetland	1100	3422	14842	27806	10873	58043
	Other	0	592	2083	3167	1410	7252